

How Closely is Potassium Mass Balance Related to Soil Test Changes?

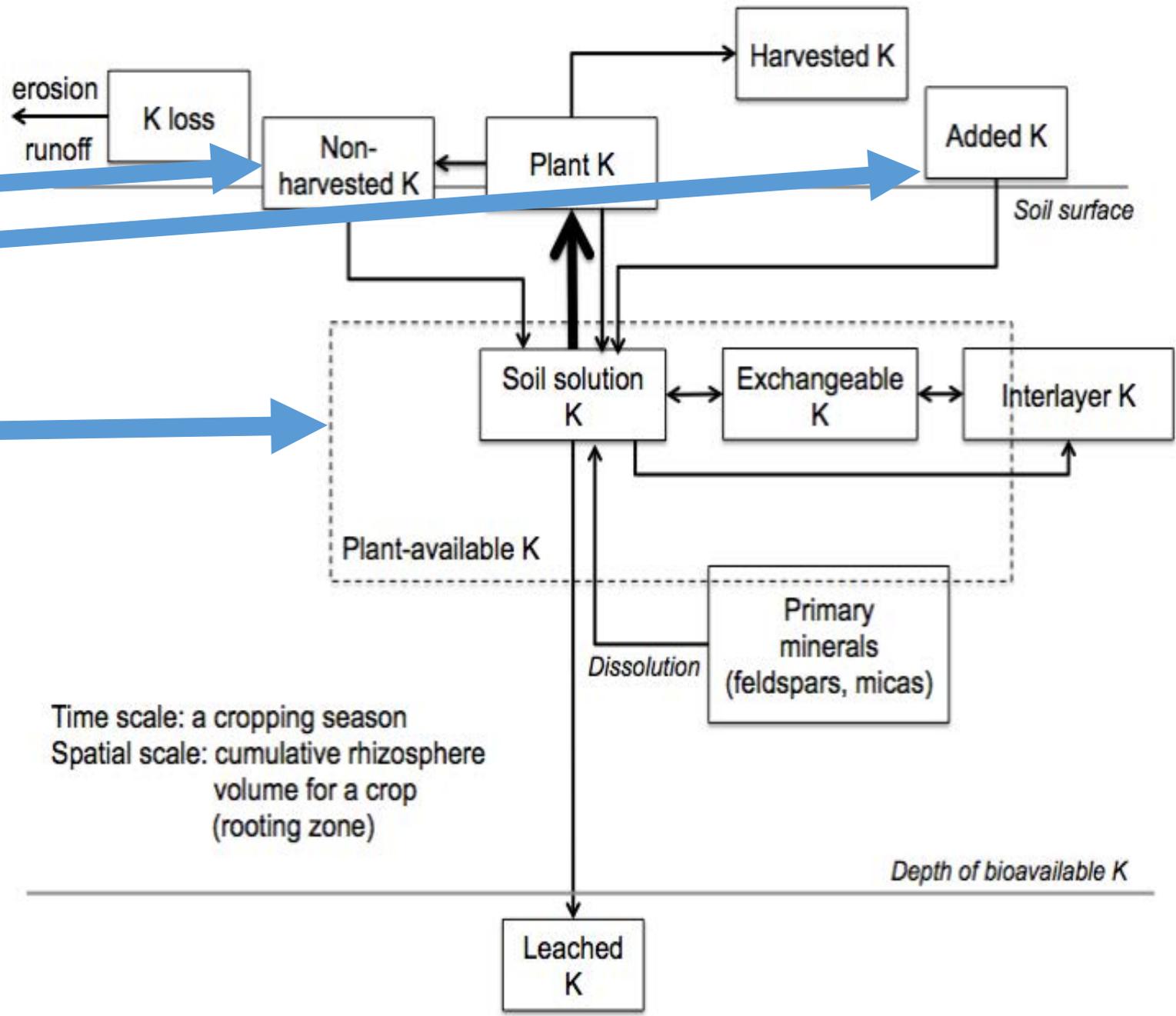
Dave Franzen- North Dakota State University, Fargo, ND, USA

Keith Goulding, Rothamsted Research, UK

Antonio Mallarino, Iowa State University, Ames, IA, USA

Michael Bell, University of Queensland, Australia

Added K
=
Measurable
and Consistent
Change in
Soil test K



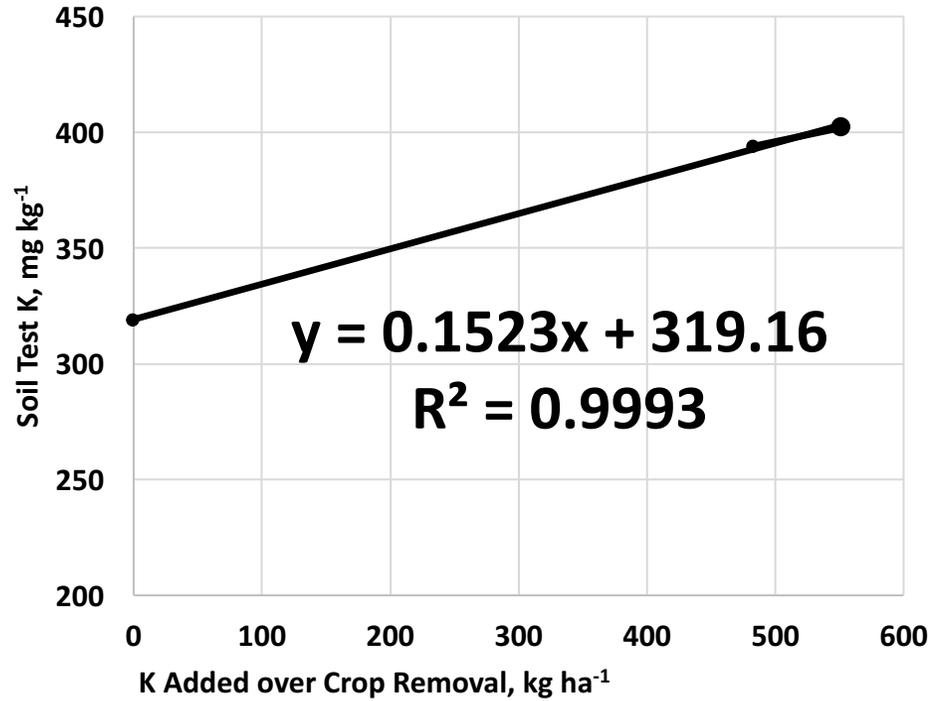
In an Illinois experiment, two 12.5 ha fields were sampled in a 24.4 m grid from 1960-1992. Corn and soybean were grown on the land either continuous corn or corn on soybean.

From 1960 until 1982, buildup K was applied.

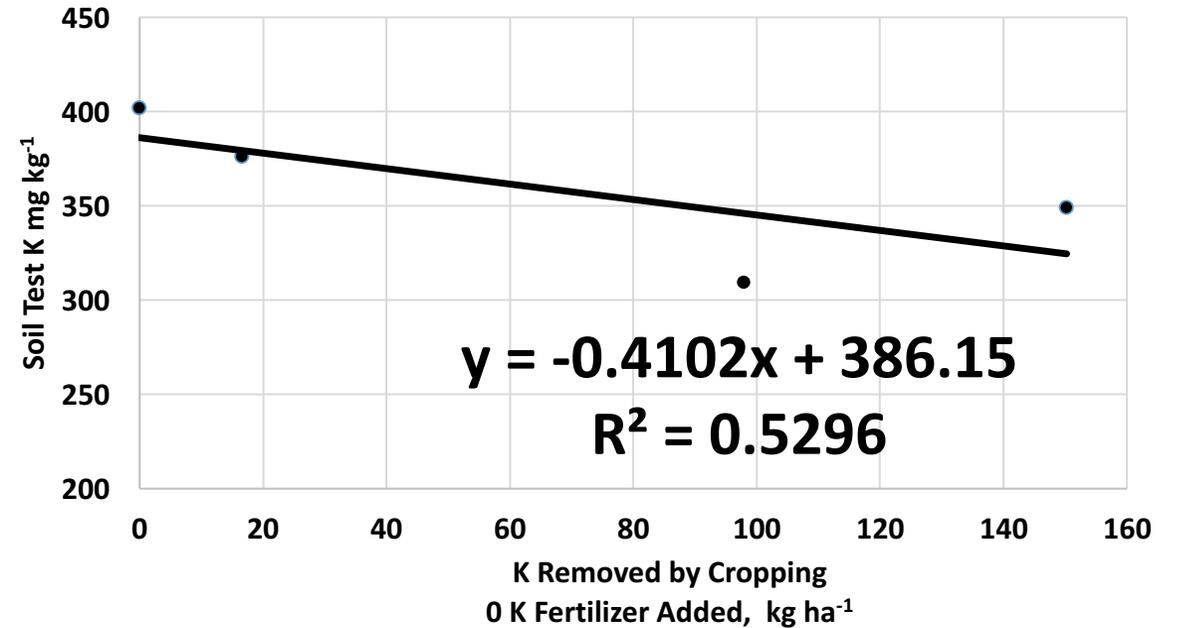
From 1982 to 1992, no additional K was applied.

If K soil test changes were directly related to K input or removal, the same changes in K soil test values would be seen whether K was added or removed.

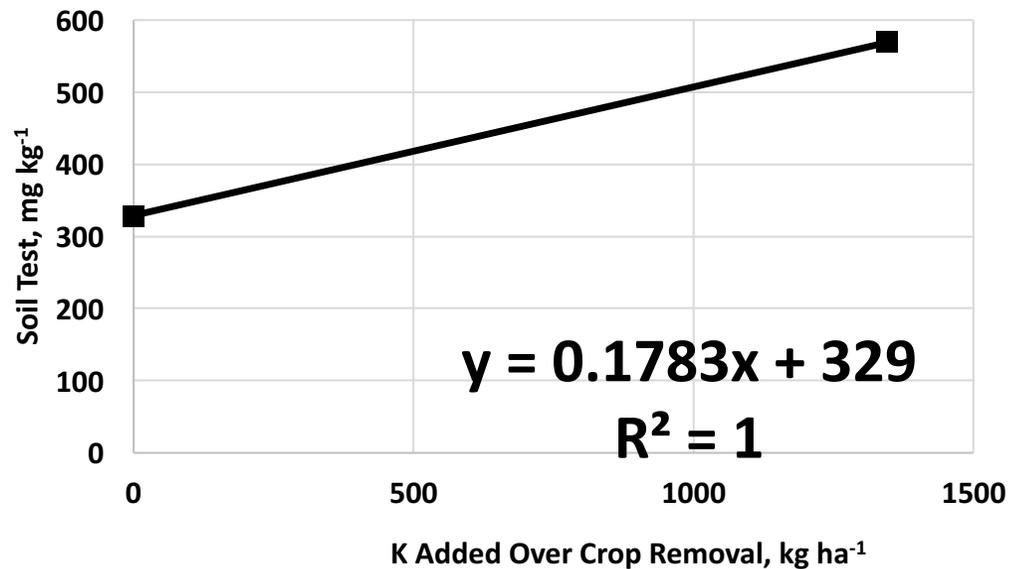
Thomasboro



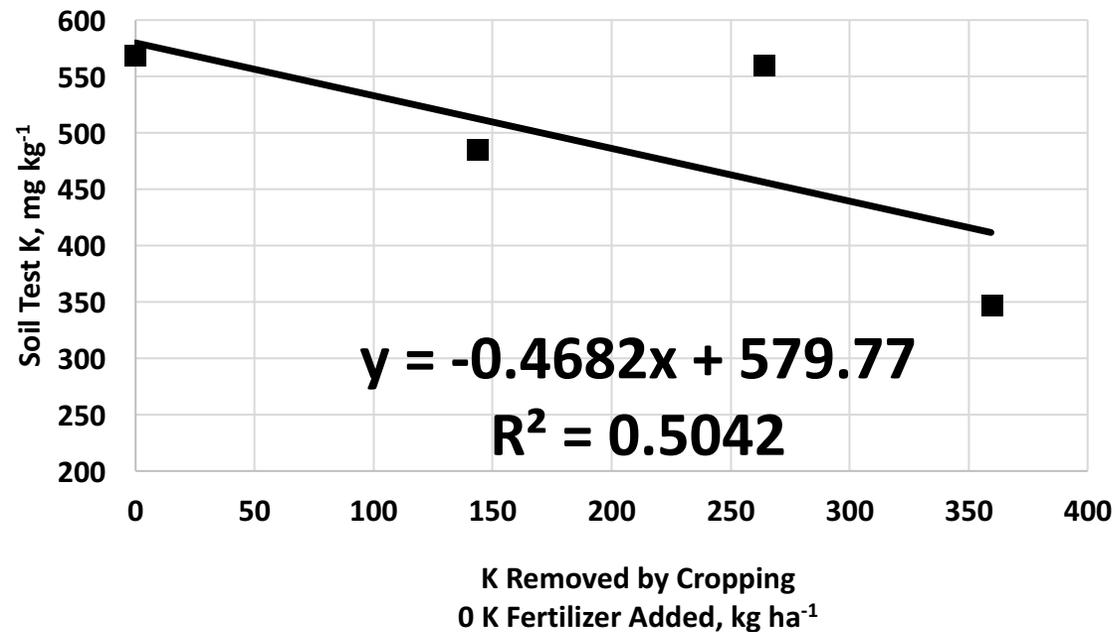
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Mansfield



Mansfield



In Iowa, in five, 16-year K rate experiments (Villavicencio, 2011), when K was not applied, decrease in soil test K did not match K removal from grain removal (Zea mays, corn, maize). Temporal variability of K was high from year to year that K removal seldom explained.

Soil test and K removal rates were related over several years, except that a soil test plateau was reached in spite of continual K removal.

Additional K was entering the soil test K system from primary minerals and/or clay interlayers.

The soils were smectitic clay dominant.

Cope (1981) followed K additions and soil test K over 50 years in Alabama, USA.

The soils were kaolinitic clay- and quartz sand- based.

Unfertilized plots reached a lower equilibrium at least 28 years following the start of the experiment.

K rates of 18 kg ha⁻¹ K resulted in no soil test change, roughly equivalent to K crop removal.

K rate greater than 18 kg ha⁻¹ K resulted in increased soil test K.

The mass-balance approach worked well in these soils.

Source of K influences the mass-balance approach-

A thirty year experiment in Germany, Poland and the UK (Rothamsted) K fertilizer with or without farm yard manure. (Blake et al., 1999)

Recovery rate from mineral fertilizer K was < 62% of applied, and related to CEC (Germany and Poland) and fixation capacity of clays (Rothamsted).

Recovery rate from mineral fertilizer K was reduced when manure was applied. Manure K is more available to crops than mineral fertilizer K.

A Canadian study also came to this conclusion. (Wang and Huang, 1991).

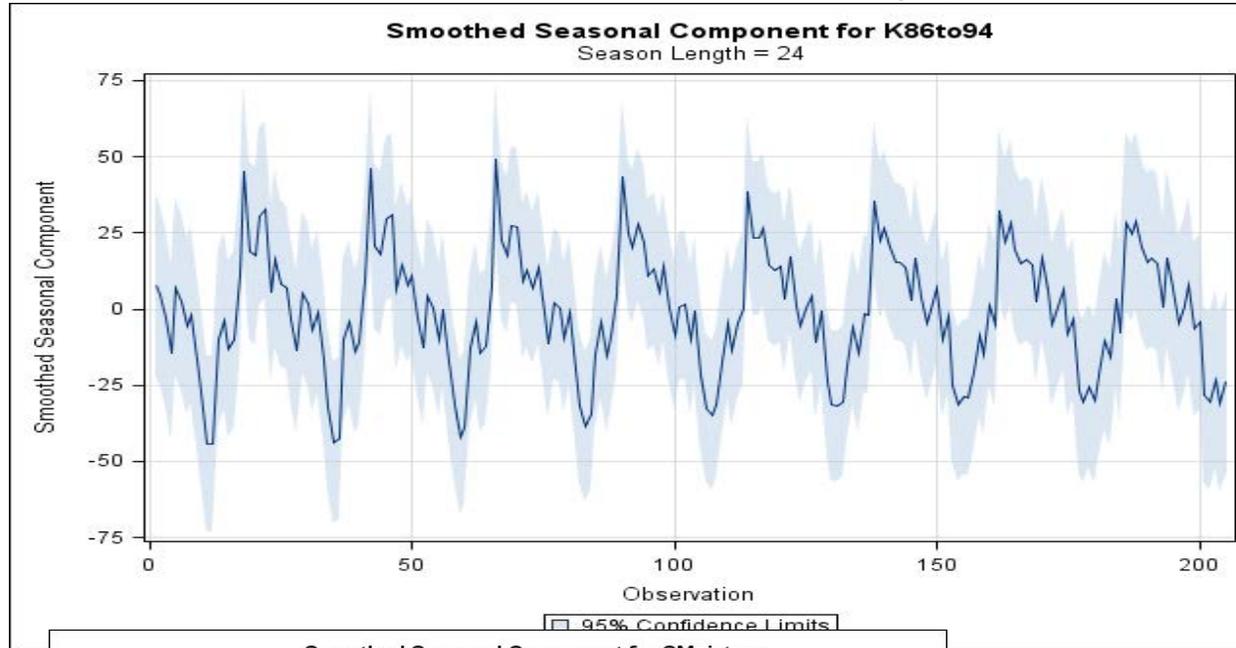
A variation of the mass-balance approach is the 'Ideal Soil', based on CEC base saturation ratios. Bear (1951) and Albrecht (1975).

Premise for the Ideal Soil is that the amount of K in soil is not as important as the ratio of K to Ca, Mg, Na, H⁺.

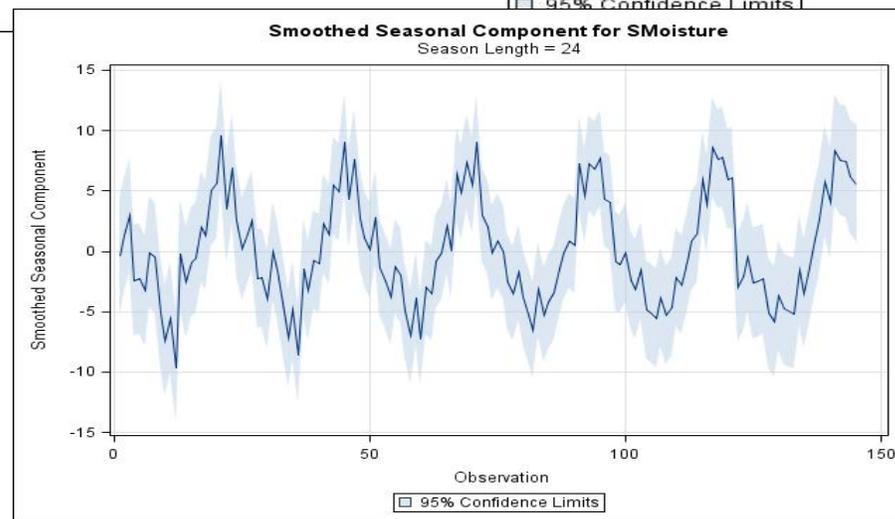
A review by Kopittke and Menzies (2007) concluded based on studies that related cation ratios to crop response to K, that the data do not support this theory, and there is no ideal ratio useful to improve crop production or relationship to K requirement. The use of the ideal soil concept would result in inefficient use of resources and inputs.

Temporal Nature of Soil Test K

Long-term study in Illinois (smectitic-dominant clays). Twice-monthly soil sampling 9 years.



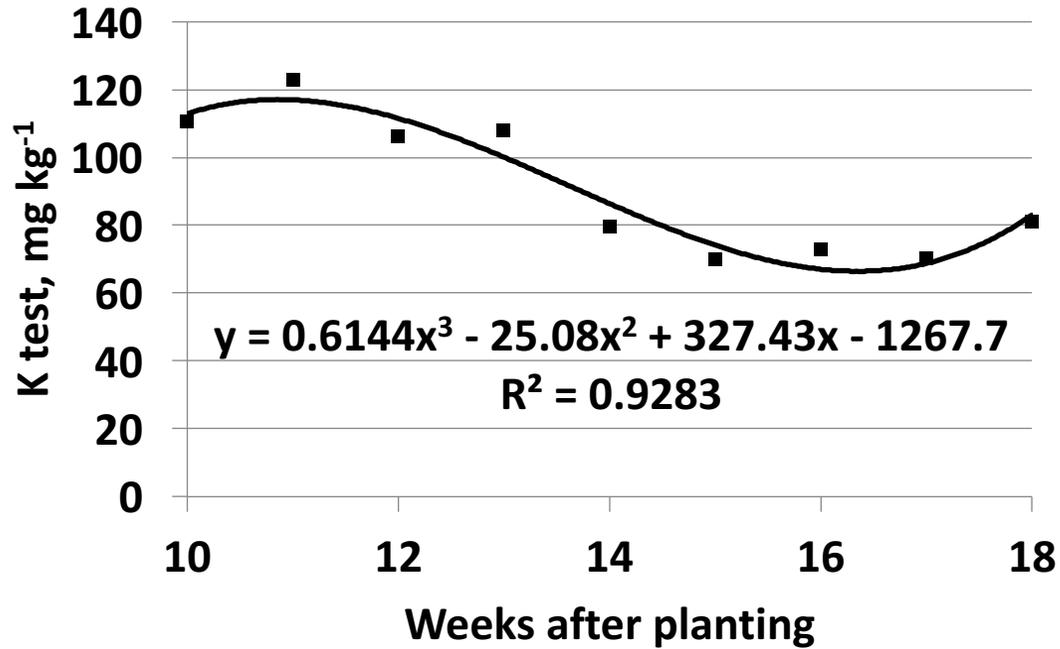
Relative soil test K



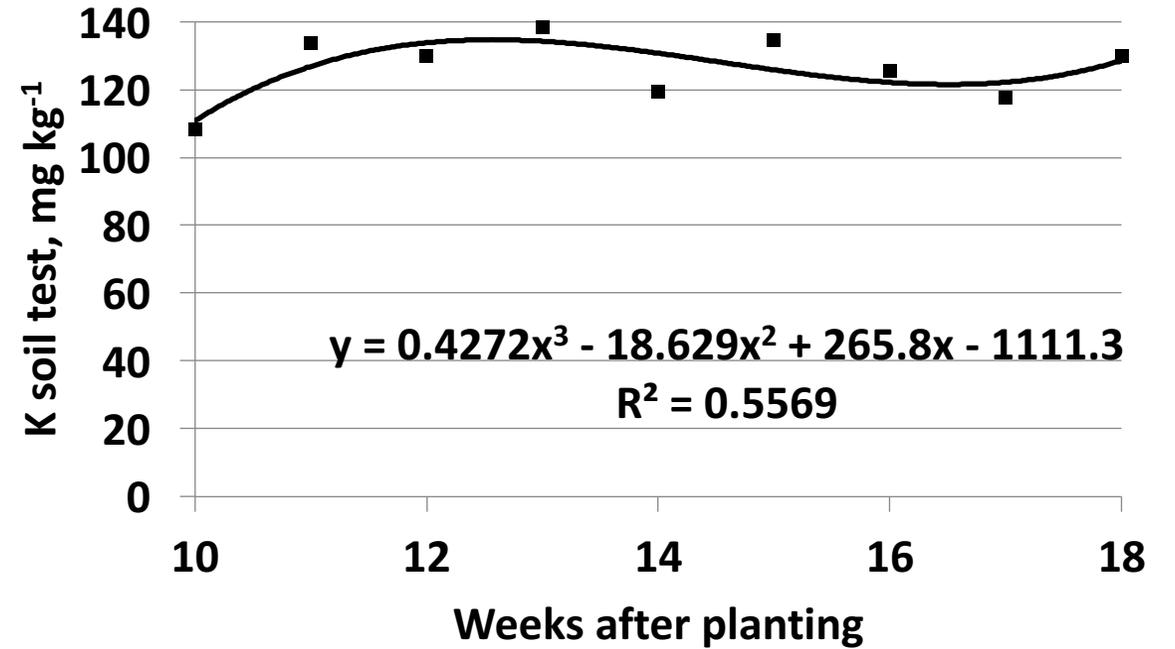
Relative soil moisture

Comparison illite-dominant soils and smectite dominant soils, North Dakota, 2016

Walcott, dominant illite, cropped

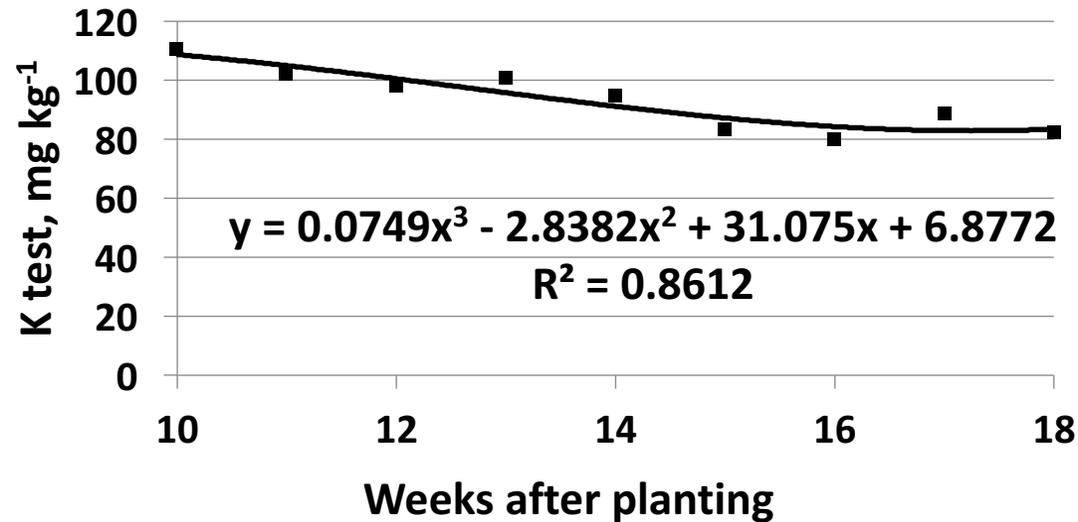


Walcott, dominant illite, fallow

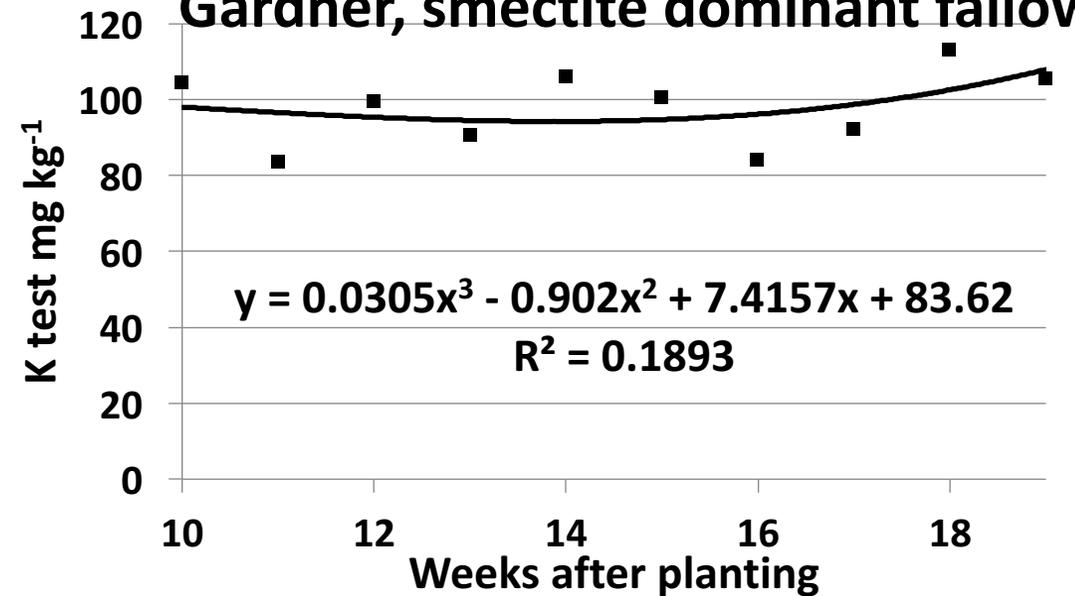


Comparison illite-dominant soils and smectite-dominant soils, North Dakota, 2016

Gardner, smectite dominant cropped



Gardner, smectite dominant fallow



One reason for temporal seasonality of soil test K is release of K from crop residue back to the soil.

Iowa- soybean K in vegetative tissues at physiological maturity (PM) to harvest (H)- $\sim 95 \text{ kg ha}^{-1} \text{ K PM}$ to $\sim 41 \text{ kg ha}^{-1} \text{ K H}$

**- corn K in vegetative tissues at PM to H-
 $\sim 100 \text{ kg ha}^{-1} \text{ K PM}$ to $\sim 66 \text{ kg ha}^{-1} \text{ K H}$**

Soybean and corn continues to release K from soybean residues until a plateau of $\sim 10 \text{ kg ha}^{-1} \text{ K}$ was reached, corn $\sim 30 \text{ kg ha}^{-1} \text{ K}$

Implications of K addition to soil from physiological maturity to some point of steady-state is that earlier sampling should either be calibrated differently or the future additions of K considered in formulating recommendations based on soil test K results.

Also, to record relative changes to soil test K over time, sampling at the same time within the same crop over years is important.

Soil sampling for K is usually conducted in the 0-15 cm depth. In soils with leaching potential, the K may not be leached below the potential maximum rooting zone, as with nitrates, but may be retained in deeper soil layers.

In soils with leaching potential, such as sandy soils or clay soils that tend to develop deep cracks, sampling the 15-30 cm depth or even deeper layers may help to explain a lack of relationship of 0-15 cm depth K soil tests with K additions.

Clay Chemistry and K Response-

Sharpley included 102 soils from continental USA and Puerto Rico in a K study.

Water soluble-K was related to exchangeable K within soils of similar clay type, but not between clay types.

Release of K from exchangeable sources into solution increased from smectite to mixed clays (illitic) to kaolinitic clays.

Summary recommended analysis of exchangeable K and K reserves (using nitric acid-extractable K) for better indication of crop K supply.

Clay Chemistry and K Response-

Bell et al., 2009 studied K fertilization in Red ferrosol (low CEC) and Black and Grey Vertisols (CEC 50-60 meq 100 g⁻¹).

Analyses of exchangeable K, soil solution K and K activity in soil solution varied 6-7 fold between soil types.

Management of K varied with soil.

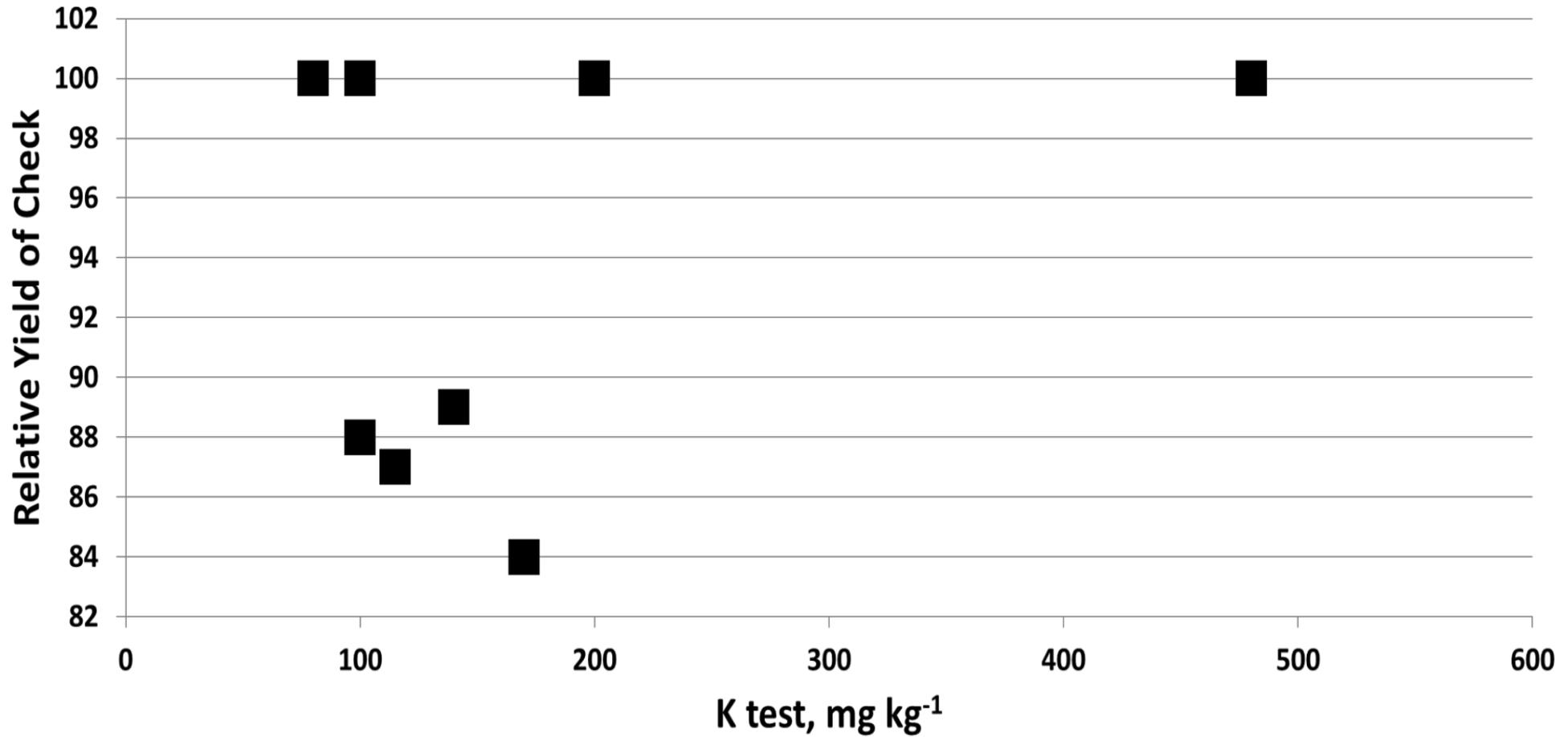
Vertisols were highly buffered and crop responded more to concentrated K fertilizer bands than broadcast.

In 2014-15 in North Dakota soils, 23 K rate experiments using maize, response of maize related to the current soil test critical level of 150 mg kg⁻¹ was predicted incorrectly at 10 sites.

Sites where the soil test would indicate yield response to K but none was seen in spite of excellent yields tended to be higher in illite relative to smectite (40%+ of total clay content).

Sites where the soil test would indicate no yield response to K but a yield response was realized tended to be sites higher in smectite (80%+).

Relative Yield of Check Compared to Maximum Yield with Dry K Test, 2014 sites



Multiple linear regression of possible factors relating to relative yield of 2014 and 2015 K rate trials in North Dakota

Factor	K test	K-feldspar	Illite	Smectite
K test	1.0			
K-feldspar	0.17	1.0		
Illite	-0.03	-0.32	1.0	
Smectite	0.05	0.33	-0.99	1.0
Relative yield	0.29	-0.0002	0.32	-0.25

Other presentations at this conference will focus on the importance of different soil K pools related to soil test K and crop response.

The interaction of K inputs or losses on the nature of soil clay type is also important in discussing mass-balance approaches to soil test K.

Barre et al. (2007) suggests that illite-dominance throughout prairie soils in general is due to the production and stabilization of illite from K redistributed from deeper soil layers to the surface through root uptake and residue decomposition. The contribution of subsoil K to crop response is seldom considered; however, the change in soil over time may need to consider the interplay between subsoil K and surface K analysis.

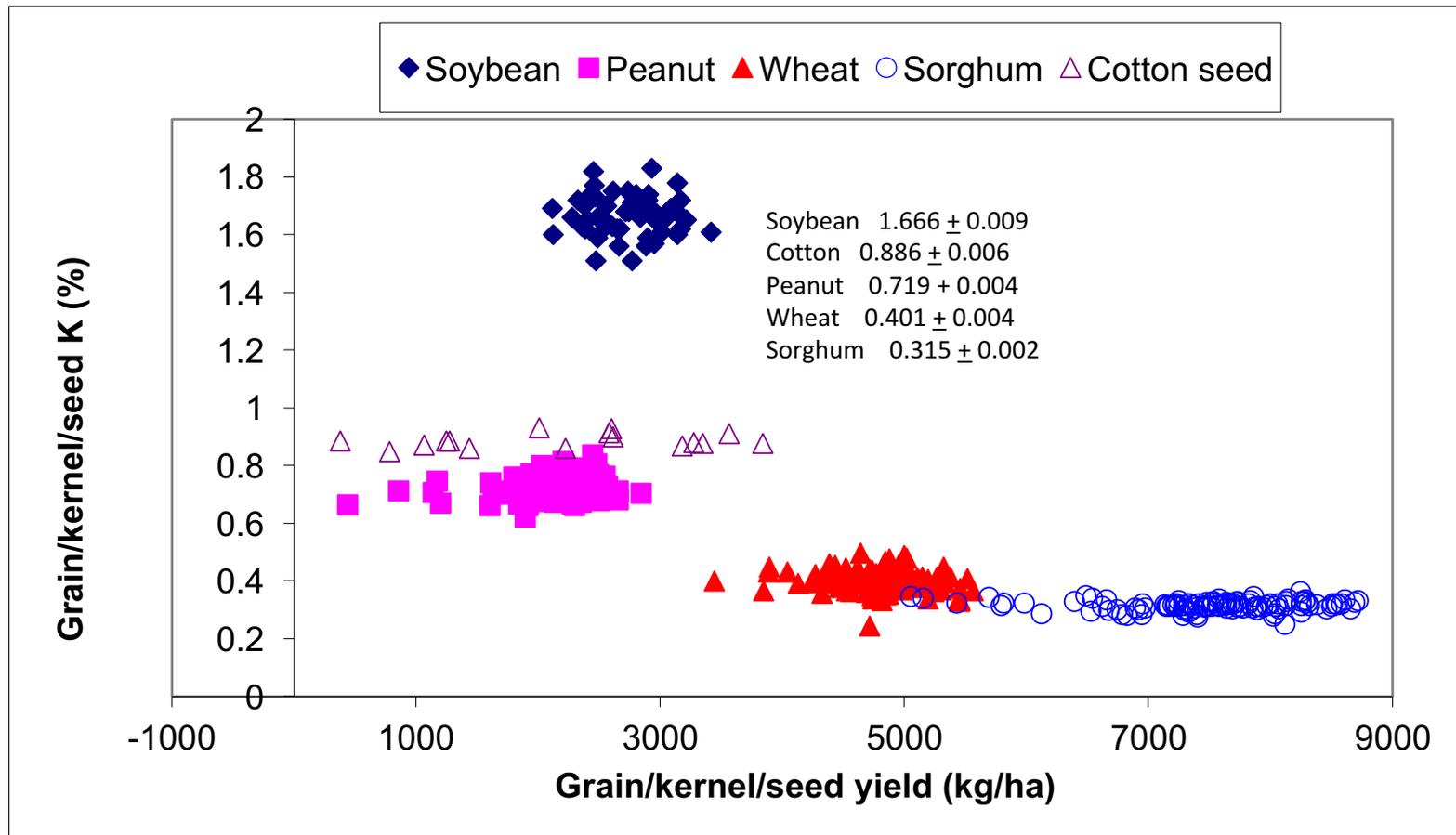
**Related to this topic is a study by De-Cheng et al. (2011).
Topsoil exchangeable K decreased due to alfalfa forage uptake and
Removal.**

**However, total topsoil K increased during this experiment due to
K additions from deep soil K taken up by alfalfa roots and
deposited in upper soil layers,
which produced a highly crystalline illitic clay, which was not
present before.**

At the Morrow Plots, University of Illinois Urbana campus Velde and Peck (2002) examined clay mineralogy with cropping and K additions. Differences in clay mineralogy between 1913 and 1996 indicate changes in clay mineralogy in unfertilized plots with continuous corn cropping. Changes were smaller in a diverse rotation (corn-oat-hay). When the NPK fertilizer treatments were introduced in 1955, the illite content of the clay mineralogy was restored.



The concentration of K in grain is relatively constant over a wide range of available soil K to the crop. Studies in Australia document a non-relationship of available soil K to K concentration in soybean seed, peanut seed, wheat grain, sorghum grain and cotton seed.



Non-Relationship of Soil Test K to Seed/Grain K Implications-

Of all the confounding factors in relating K additions, losses to soil test K, the relatively constant K concentration within a grain or seed species is refreshing.

Researchers and practitioners can confidently use a value over a range of fields to calculate crop removal and be very close to the actual value.



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PHOTO BY PAUL K. MYERS
DUST STORM - HURON, S.D. Nov. 12, 1933. 11:55 A.M.

Image property of D.W. Franzen, Fargo, 1930's postcard



Soil loss- 1930's-

Black is 'moderate wind erosion' 25-75% topsoil loss

Grey dotted is 'slight' wind erosion- 25% topsoil loss

Oblique slash is total wind/water erosion- moderate- 75% topsoil loss

From 'General Distribution of Erosion, USDA- 1936

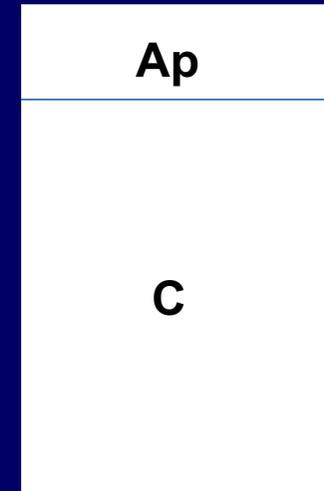
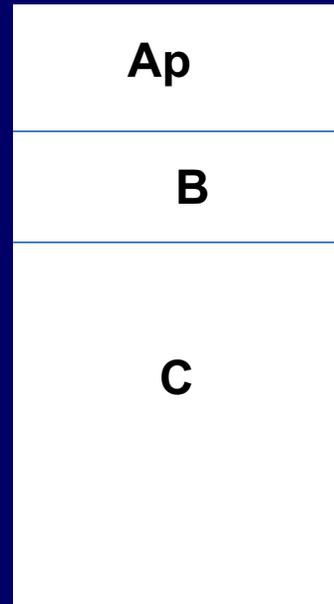
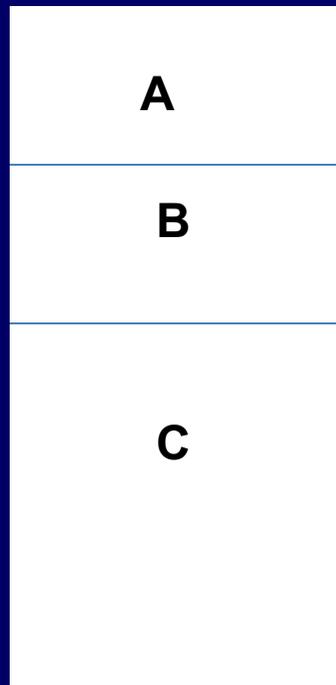
(Note-only the first half of the '30's)

Analysis of dust in the 1930's compared to the soil that remained showed that there was 19 times more P_2O_5 in the dust than in what was left.

**Also 10 times more organic matter,
9 times more nitrogen, and
45 times more potassium.**

(Small Farms, Externalities and the Dust Bowl of the 1930's.
Hansen, Z.K., and Lidecap, G.D., 2004, Journal of Political Economy)

Simultaneous cultivation and erosion on hidden soil losses and truncation of the soil profile



A North Dakota site northwest of Grand Forks

1958

Ap 0-16 cm

Bk1- 16-42.7 cm

Bk2 42.7 to 87 cm

C 87 cm+

2014

Ap 0- 13 cm

Bw1 13 – 28.4 cm

Bw2 28.4 – 38 cm

C 38 cm +

**Data indicates site
lost about 49 cm
topsoil in the
past 56 years**

**Estimate of topsoil lost from date of plowing
to late 1930's-**

about 30 cm from hilltops
and about 20 cm from slopes.

**An average of 15 cm topsoil lost in North Dakota
from about 11.8 million ha of cropland.
Total weight ~ 27.3 billion tonnes of soil.**

The K content of soil is about 1.6% in North Dakota
Total K lost would have been 440 million tonnes-
or 880 years of K application at present rates.

North Dakota has probably lost an additional 15 cm of topsoil from 8 M ha since 1940, This means that we have lost an additional 176 M tonnes of K, equivalent to another 220 years of K application at present rates by farmers within the state.

Summary-

Mass-balance of K is a function of-

- K additions from mineral and organic fertilizer**
- Plant redistribution of subsoil K to the surface soil**
- K losses due to leaching in low CEC soils requiring deeper sampling**
- K removal with grain forage and crop residues**
- K lost in soil erosion from wind/water**

Summary-

A mass-balance relationship between K inputs and losses with soil test K is rarely achieved due to the rapid equilibrium between soil solution K, exchangeable K, K-bearing primary minerals and clay interlayer K.

In addition, soil moisture, K uptake by crop and K release from residues, organic matter contribution to soil CEC, and type of K amendment confound most attempts to achieve a mass-balance.